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EXTRACTION OF QUANTITATIVE SURFACE CHARACTERISTICS FROM AIRSAR DATA FOR DEATH VALLEY, CALIFORNIA

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1. INTRODUCTION

Polarimetric Airborne Synthetic Aperture Radar (AIRSAR) data were collected for the Geologic Remote Sensing Field Experiment (GRSFE) over Death Valley, California, USA, in September 1989 (Evans and Arvidson, 1990; Arvidson et al, 1991). AIRSAR is a four-look, quad-polarization, three frequency instrument. It collects measurements at C-band (5.66 cm), L-band (23.98 cm), and P-band (68.13 cm), and has a GIFOV of 10 meters and a swath width of 12 kilometers. Because the radar measures at three wavelengths, different scales of surface roughness are measured. Also, dielectric constants can be calculated from the data (Zebker et al, 1987).

The AIRSAR data were calibrated using in-scene trihedral corner reflectors to remove cross-talk; and to calibrate the phase, amplitude, and co-channel gain imbalance (van Zyl, 1990). The calibration allows for the extraction of accurate values of rms surface roughness, dielectric constants, σ_0 backscatter and polarization information. The radar data sets allow quantitative characterization of small scale surface structure of geologic units, providing information about the physical and chemical processes that control the surface morphology. Combining the quantitative information extracted from the radar data with other remotely sensed data sets allows discrimination, identification and mapping of geologic units that may be difficult to discern using conventional techniques.

2. INVERSION AND ANALYSIS

The first-order small perturbation model (van Zyl et al ,1991; Valenzuela, 1967) was used to estimate the surface power spectral density at every pixel by performing an inversion of the AIRSAR data. This model is valid only for very smooth surfaces. Therefore, only playa, smooth salt pans and alluvial fan surfaces were used in this study. Results from the small perturbation model inversion are three values, one for each of the radar frequencies, that describe the power spectral density of the surface. The power spectrum of a geologic surface is approximately linear in log-log space (Brown and Scholz, 1985). Fitting the three points from the inversion with a line using a least-squares method produces slope and intercept values that allow calculation of the fractal dimension of the surface and a rms surface roughness value.

The slope of the power spectrum is related to the two-dimensional fractal dimension of the surface. The fractal dimension of a surface describes the scaling properties of the topography (Mandelbrot, 1982). A surface may have a fractal dimension between 2 and 3 and as the fractal dimension increases, heights of nearby points become more independent (Brown and Scholz, 1985). The intercept of the power spectrum can be directly related to a rms surface roughness using forward modelling. Using the fractal dimension and rms surface roughness calculated from the radar inversion power spectrum, a synthetic three dimensional plot can be made that represents the surface (Huang and Turcotte, 1989; Kierein-Young et al, 1992).

3. RESULTS AND CONCLUSIONS

Radar inversions were performed using two dielectric constant cases for polygon averages of four surfaces in Death Valley. The surfaces include a playa, smooth salt, alluvial fan with desert pavement, and a rough alluvial fan. In both of the dielectric constant cases, the rms surface roughness is smallest for the playa, increases for the smooth salt and fan with desert pavement, and is largest for the rough fan. The fractal dimension is largest for the smoothest surface, the playa, and smaller for the rougher surfaces. This indicates that nearby points on the smoother surfaces are more independent and nearby points on the rougher surfaces are more correlated. Therefore, the smooth surfaces have a more equal distribution of all wavelengths of roughness while the rough surfaces have more longer wavelength roughness. Figure 1 shows the synthetic surfaces for the four areas with the dielectric constants equal to 3.0. In the case when dielectric constants are calculated in the inversion, some bad values were obtained so more analysis is needed. In this case the fractal dimensions are slightly smaller and the rms roughness values are higher than in the dielectric constant equals 3.0 case. The values of the dielectric constants calculated in the inversion fall within a reasonable range for the surfaces studied (Ulaby et al, 1982). Dielectric field and laboratory measurements will be made to verify the accuracy of these values.

Combining knowledge of the surface structure and roughness of geologic units with data from other instruments allows for the determination of the processes that control the surface. For example, water vapor and liquid water maps were generated from Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data in Death Valley (Kierein-Young and Kruse, 1991). These maps show the distribution of a hydrological process, the water content of the surface. The water distribution was found to correspond with the surface roughness variations where wet areas are smooth and drier areas rougher. The combination of surface water distribution with surface structure information will help in determining why the salt flats are spatially variant.

4. ACKNOWLEDGEMENTS

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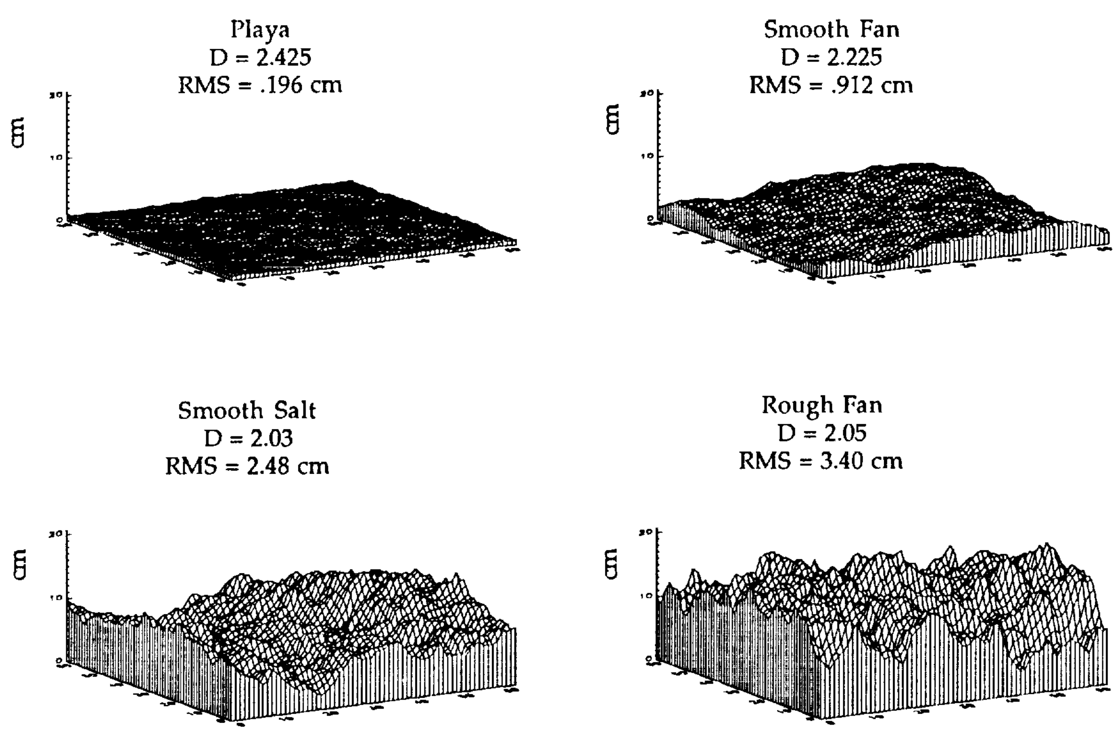

Figure 1. Synthetic surfaces calculated from radar inversion results assuming dielectric constants equal to 3.0.